Wicking behaviour of air-jet textured yarns

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Wicking behaviour of air-jet textured yarns has been studied in relation to surface structure, core diameter, spin finish, fibre cross-sectional shape and yarn tension. It has been observed that increasing percentage of floats and arcs and higher percentage increase in core diameter improves the wicking behaviour. Yarns with spin finishes show higher wicking height as well as higher wicking rate as compared to yarns without spin finishes. Trilobal filament yarns show better wicking properties than the yarns produced from circular filaments. The yarn tension has also been found to influence the wicking height.

Keywords: Air-jet textured yarns, Core diameter, Fibre cross-sectional shape, Floats and arcs, Spin finish, Surface structure, Wicking, Yarn tension

1 Introduction
The properties of air-jet textured yarns have been reported to a limited extent1-6. However, no information regarding the wicking behaviour of these yarns has yet been reported. Wicking behaviour of yarns is extremely important from the point of view of comfort characteristics of fabrics made from yarns. Structure of air-jet textured yarns is unique in the sense that, in addition to the core, surface of the yarns show different types of loops of varying shapes and sizes. The wicking behaviour can be affected by both core and surface structure of yarns. In addition, type and amount of spin finish, fineness and cross-sectional shape of filaments and tension level in yarns may affect the wicking behaviour of air-jet textured yarns. The effect of some of these parameters on wicking behaviour has been studied and is reported.

2 Materials and Methods
Four different polyester yarns of 68 circular filaments (2.44 dtex per filament) with different spin finishes and a yarn of 68 trilobal filaments (2.44 dtex per filament) were textured. Eltex AT/HS air-jet texturing machine and HemaJet with T100 core were used to produce air textured yarns with the texturing parameters of 33.3% overfeed, 9 kg/cm² air pressure and 300 m/min speed. Yarns were produced under both dry and wet texturing conditions. The difference between wet and dry texturing is that in the former case the parent yarns are wetted prior to their entry into the texturing jet, whereas in the latter case, parent yarns are directly fed into the texturing jet. In the case of wet texturing, HamaWet system with 2 kg/cm² water pressure and 1 litre/h water consumption rate was used. After texturing, yarns were tested with the spin finish as well as after a spin finish extraction treatment for equilibrium and dynamic wicking behaviour. This was done to find out the effects of spin finishes and structural parameters of textured yarns on the wicking behaviour. A much coarser yarn of 2/166 dtex/34 filaments was also textured and the effect of yarn tension on equilibrium wicking height was studied.

2.1 Test Methods
Core diameter and surface characteristics of air-jet textured yarns were determined using the method described earlier7. The % increase in core diameter of textured yarn from the parent yarn diameter is given by the following formula

\[
\text{Increase in core diameter, } \% = \frac{\text{Core diameter of textured yarn}}{\text{Diameter of parent yarn}} \times \frac{\text{Diameter of parent yarn}}{\text{Core diameter of textured yarn}} \times 100
\]

The physical bulk (%) of textured yarn was measured by the package density method as suggested by Du Pont8. The wicking behaviour of
both parent and air-jet textured yarns with or without spin finish was determined following the procedure described below.

Methylene Blue solution with a concentration of 1% was used to study the equilibrium and dynamic wicking behaviour. Air-jet textured yarn with a tension of 0.017 cN/dtex was hung vertically from a clamp into the bath containing the prepared dye solution. The tension in the yarn was maintained by attaching the required weight to the bottom end of the yarn by means of a hook. A scale was attached very near to the yarn to measure the equilibrium wicking height. The equilibrium wicking height was measured after 12 h from the time of dipping the yarn in the dye bath. In the case of wicking rate, the time required for the dye solution to travel upwards along the yarn for every 1 cm length of yarn, up to a maximum of 5 cm, was noted with the help of a stop watch and a travelling microscope. Thirty and sixty readings were taken for equilibrium height and wicking rate tests respectively. The % increase in equilibrium wicking height of textured yarn from the wicking height of parent yarn was calculated as follows:

\[
\text{Increase in equilibrium wicking height, } \% = \frac{\text{Equilibrium wicking height for textured yarn} - \text{Equilibrium wicking height for parent yarn}}{\text{Equilibrium wicking height for parent yarn}} \times 100
\]

3 Results and Discussion

Fig. 1 shows the relationship between equilibrium wicking height and percentage of floats and arcs for both dry- and wet-textured yarns. For the same percentage of floats and arcs, the trilobal filament yarns show better wicking properties. The equilibrium wicking height tends to increase with an increase in the percentage of floats and arcs. As the air-jet textured yarns have bipartite structure with core and surface loops, the configuration of loops and their frequency may influence the wicking behaviour, since part of the liquid travels through the periphery of the yarn. Presence of long drawn out loops like floats and arcs offers less tortuous path to the liquid to travel; as a result, higher percentage of floats and arcs lead to higher wicking height.

Yarns without spin finishes have lower wicking height. 't' test conducted shows that the wicking heights of spin finish freed yarns are significantly lower than the wicking heights of the corresponding yarns with spin finishes at 5% significant level.

Yarns with and without spin finishes have correlation coefficients of 0.58 and 0.72 between equilibrium wicking height and percentage of floats and arcs respectively. The poor correlation coefficient for the textured yarns with spin finishes may be ascribed to the variation in the type of spin finishes and their levels on different textured yarns. It has been shown that the spin finish is not removed from the surface of the yarn when dry textured, but the level of spin finish is reduced by 67-85% of the original level during wet texturing. The extent of removal of spin finish during wet texturing depends on the type of spin finish used. Yarns freed from spin finishes show better correlation between percentage of floats and arcs and wicking heights compared to yarns with spin finishes, as the wicking height of textured yarns mainly depends on the structural parameters, once the spin finishes are removed. In order to separate the influence of wicking behaviour of parent yarns from the wicking behaviour of the textured yarns, the percentage increase in wicking height of spin finish freed textured yarns from that of corresponding spin finish freed parent yarns are plotted against the percentage of floats and arcs in Fig. 2. The percentage increase in equilibrium wicking height gives a correlation coefficient of 0.72, which is identical to the one obtained between equilibrium wicking height and percentage of floats and arcs.

Fig. 3 shows the relationship between percentage increase in wicking height and percentage increase in core diameter of textured yarns with circular
The percentage increase in wicking height is measured after removing the spin finishes for both the parent and textured yarns. Wicking improves with the increase in core diameter and the relationship has a correlation coefficient of 0.68. Moreover, the increase in core diameter of long drawn-out loops (floats and arcs), shown in Table I for both parent and textured yarns, is higher than that of corresponding wet textured yarns. The presence of more number of loops in the case of wet textured yarns may, in fact, increase the number of obstructing surfaces against the liquid to wicking height. The correlation coefficient of 0.68 suggests that both core diameter and the relationship between percentage increase in core diameter and percentage increase in core diameter of long drawn-out loops are higher than that of corresponding wet textured yarns.

Table 1—Percentage increase in core diameter, physical bulk, percentage of floats and arcs, and percentage increase in wicking height for spin finish extracted yarns

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Specification</th>
<th>Parent yarn diameter (× 0.001), mm</th>
<th>Textured yarn diameter (× 0.001), mm</th>
<th>Increase in core diameter %</th>
<th>Physical bulk %</th>
<th>Loops per cm</th>
<th>Floats and arcs %</th>
<th>Wicking height of spin finish freed yarns, mm</th>
<th>Increase in wicking height %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/83/34 Sd1</td>
<td>WT</td>
<td>151</td>
<td>9.24</td>
<td>277</td>
<td>20</td>
<td>83.4</td>
<td>269</td>
<td>139</td>
<td>33.9</td>
</tr>
<tr>
<td>2/83/34 Sd2</td>
<td>WT</td>
<td>151</td>
<td>10.6</td>
<td>276</td>
<td>22</td>
<td>82.8</td>
<td>240</td>
<td>131</td>
<td>40.0</td>
</tr>
<tr>
<td>2/83/34 Bt</td>
<td>WT</td>
<td>199</td>
<td>7.92</td>
<td>290</td>
<td>26</td>
<td>94.6</td>
<td>256</td>
<td>143</td>
<td>38.8</td>
</tr>
<tr>
<td>1/166/68 Bt</td>
<td>WT</td>
<td>149</td>
<td>8.98</td>
<td>294</td>
<td>20</td>
<td>97.3</td>
<td>249</td>
<td>131</td>
<td>41.3</td>
</tr>
<tr>
<td>2/83/34 Sd1</td>
<td>DT</td>
<td>199</td>
<td>9.24</td>
<td>317</td>
<td>22</td>
<td>110.0</td>
<td>237</td>
<td>126</td>
<td>45.4</td>
</tr>
<tr>
<td>2/83/34 Sd2</td>
<td>DT</td>
<td>151</td>
<td>10.6</td>
<td>326</td>
<td>23</td>
<td>116.0</td>
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<td>46.2</td>
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<tr>
<td>2/83/34 Bt</td>
<td>DT</td>
<td>149</td>
<td>7.92</td>
<td>330</td>
<td>26</td>
<td>121.0</td>
<td>229</td>
<td>113</td>
<td>55.8</td>
</tr>
<tr>
<td>1/166/68 Bt</td>
<td>DT</td>
<td>149</td>
<td>8.98</td>
<td>344</td>
<td>24</td>
<td>131.0</td>
<td>225</td>
<td>119</td>
<td>60.1</td>
</tr>
</tbody>
</table>

*Polyester yarns of 68 filaments with 2.44 dtex per filament with circular cross-section.
DT—dry textured, WT—wet textured, Sd1—semidull finish 1, Sd2—semidull finish 2, Bt—bright finish, and s.d.—standard deviation.
travel, which results in low wicking height compared to that in the case of dry textured yarns. Bulkier core and more number of floats and arcs for dry textured yarns tend to enhance the wicking behaviour of these yarns by providing more spaces in the core and less tortuous path to the liquid to travel respectively.

Fig. 4 shows the wicking height in relation to the tension for both the spin finish freed parent yarn and the corresponding textured yarn. The wicking heights increase initially and then decrease with increasing tension levels for both parent and textured yarns. The filaments try to align themselves with an increasing tension, presenting straight paths, as a consequence of which more wicking height is observed. The reduction in bulk levels for the textured yarn would be quite low at the tension level of 0.4 cN/tex which corresponds to the maximum wicking height for the textured yarn. However, at higher tension levels, the yarns tend to lose a part of its bulk due to lessening of interfilament space as the filaments come closer to each other. This decreases the wicking heights in spite of improvements in the alignment of the filaments towards the yarn axis.

Higher wicking height for air-jet textured yarn compared to that for its parent yarn, and the reduction in wicking height at higher yarn tensions for both the parent and textured yarns (Fig. 4) suggest that wicking is related to bulk levels, but the relationship between physical bulk (%) and wicking height observed in Table I fails to show any clear trend. The inter-relationship between bulk, form and frequency of loops and core diameter, and the dependence of wicking behaviour on all these parameters makes the analysis a little too complicated for assessment of the relative contribution of each parameter to the equilibrium wicking behaviour of textured yarns, particularly for yarns with various structures and bulk levels. This may be the reason for low correlation coefficients (<0.72) between wicking height and structural parameters of textured yarns. However, the test method suggested above allows the measurement of wicking behaviour of air-jet textured yarns and can be used for the purpose of quality control during the production of air-jet textured yarns and in assessing the likely comfort properties of fabrics made from these yarns. The dynamic wicking behaviour of both circular and trilobal filament yarns is shown in Fig. 5. Yarns of trilobal filaments have faster wicking rate than the circular filament yarns. The trilobal filament yarn has larger core diameter (0.388 mm) compared to that of the circular filament yarn (0.326 mm). However, trilobal filament yarn has less percentage of floats and arcs (41%) than for circular filament yarns (46.2%). The inherent bulkiness of trilobal filament may be the reason for better wicking rate of trilobal filament yarns. It is also observed from Fig. 5 that the wicking rate is more sensitive to the spin finish rather than the structure of air-jet textured yarns and constituent filaments.

4 Conclusions

The equilibrium wicking height of a yarn with spin finish is higher than the equilibrium wicking height of the spin finish freed yarn. Presence of higher proportion of long drawn out loops, like floats and arcs, and larger core diameters of air-jet textured yarns increases the equilibrium wicking height. The wicking heights for wet textured yarns are lower
compared to those for dry textured yarns. The inter-relationships between core diameter, bulk, loop frequency and configuration of loops and their influence on wicking height make the analysis difficult in assessing the relative contribution of each of these parameters to the equilibrium wicking behaviour of air-jet textured yarns, as all these parameters vary and it is not possible to vary just one parameter at a time. Trilobal filament yarns have better wicking properties (both in equilibrium and dynamic conditions) than circular filament yarns.

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References